Drought Monitoring and Outlook Systems in a Non-stationarity World

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Drought and Non-stationarity: Information Gathering Session 2
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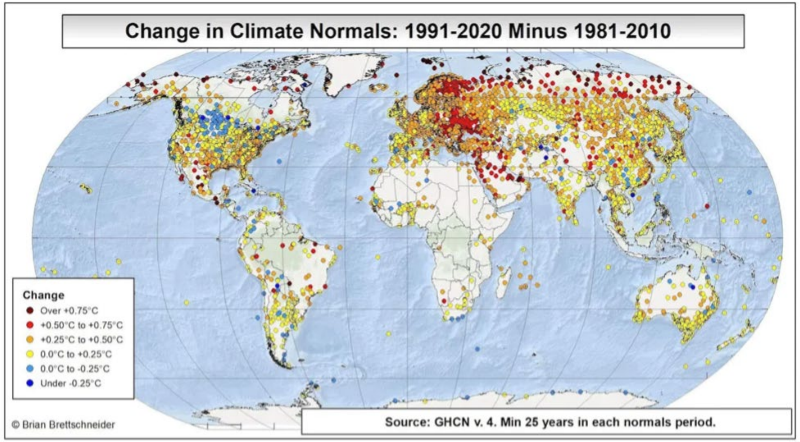
Recognizing non-stationarity in drought monitoring and prediction

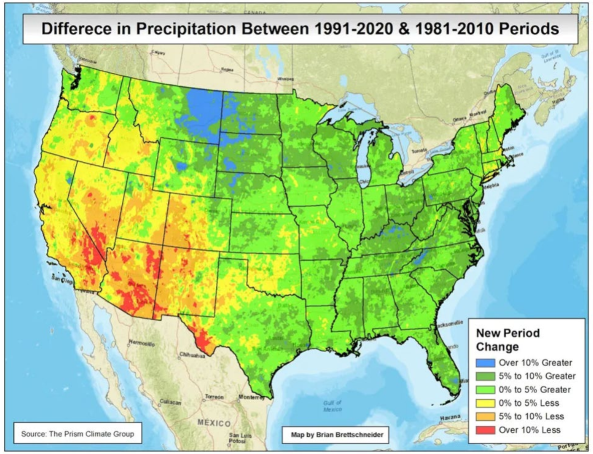
The general challenge: Trends and/or low-frequency variability in climate variables undermine the utility of anomaly-based metrics (e.g., indices) for managing sectoral impacts.

- Phenomena such as aridification lead to societal and sectoral adaptations over time, while metrics based on fixed climatology assumptions are maladaptive
  - "Is a "drought" really occurring if aridity is the "new normal" (Hoylman et al, 2022)
- Such metrics for tracking variability and change for other purposes may be well justified (not the topic here)

- Current practice in drought monitoring and prediction **does** reflect some non-stationarity in expected climate
  - Decadal updates to 'normals' period used in calculating common drought indices (e.g., SPI, SPEI, SRI)
  - Is this responsive enough?



Based on this preliminary map, nearly all of the world was warmer in 1991-2020 than in 1981-2010. One of the few exceptions is the north central U.S. and south central Canada. (Image credit: Brian Brettschneider, University of Alaska Fairbanks, using data from the Global Historical Climatology Network)



Most parts of the United States east of the Rockies were slightly wetter in 1991-2020 compared to 1981-2010, while the Southwest was notably drier. (Image credit: Brian Brettschneider, based on data from the PRISM Climate Group/University of Oregon)

Images source: https://yaleclimateconnections.org/2021/02/updated-yardstick-begs-question-whats-normal-in-a-changing-climate/

Hoylman, Z.H., Bocinsky, R.K. & Jencso, K.G. **Drought assessment has been outpaced by climate change: empirical arguments for a paradigm shift**. Nat Commun 13, 2715 (2022). https://doi.org/10.1038/s41467-022-30316-5

Recognizing non-stationarity in drought monitoring and prediction

Using shifting ('rolling') reference periods to define extremes thresholds is warranted

- Not a new or complicated idea, but the implementation requires careful consideration

The obvious alternative to a decadally-updated climate normal is to update the 30-year average annually … Simple calculations using monthly mean temperature data demonstrate that for station-month time series exhibiting strong relative trends, annually-updated climate normals can outperform decadally-updated normals over 90% of the time as the decadal average becomes more out-of-date during the intervening decade between calculations of standard WMO climate normals. (Arguez & Vose, 2011)

- Pros
  - avoids sudden large shifts in normals each decade
  - allows for regions to slide from drought to permanently arid, or vice versa
  - **simple, incremental adjustment to long-standing practice**

- How it could be sub-optimal?
  - annual updates may be too frequent for input data quality control and product generation, release, messaging
  - user/stakeholder data practices may not be able to respond, may lag
  - temptation to jump in complexity (more advanced stat/ML modeling)

The Definition of the Standard WMO Climate Normal

The Key to Deriving Alternative Climate Normals

BY ANTHONY ARGUEZ AND RUSSELL S. VOSE

Arguez, A., and R. S. Vose, 2011: **The Definition of the Standard WMO Climate Normal: The Key to Deriving Alternative Climate Normals**. Bull. Amer. Meteor. Soc., 92, 699–704, https://doi.org/10.1175/2010BAMS2955.1.

Arguez, A., et al., 2019: **ENSO Normals: A New U.S. Climate Normals Product Conditioned by ENSO Phase and Intensity and Accounting for Secular Trends**. J. Appl. Meteor. Climatol., 58, 1381–1397, https://doi.org/10.1175/JAMC-D-18-0252.1.

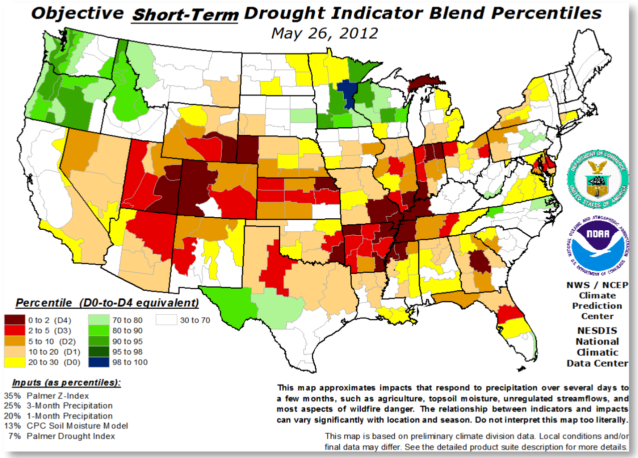
The need for an objective paradigm in drought monitoring

For the last several decades, official federal drought monitor (eg, USDM) (and outlook) products have been at least partly subjective.

- Author subjectively assembles a consensus outlook
- Draws upon a wide range of climate and other analyses
- Review with drought panel (federal, state, local, stakeholder)
- Final map drawn, converted to GIS, published

Desk of USDM author circa 2012

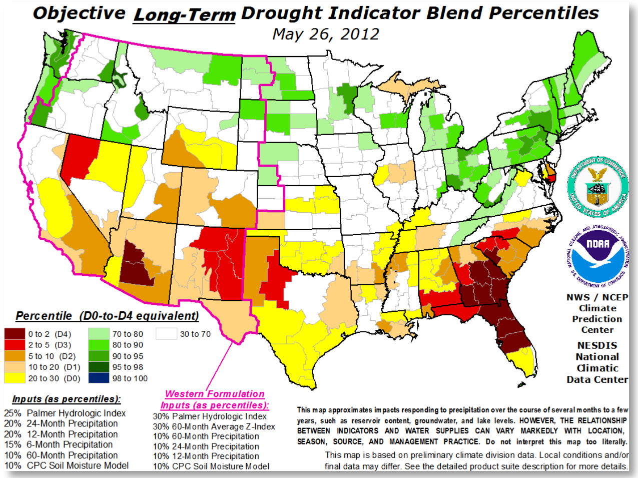
photo: M. Svoboda, 2012



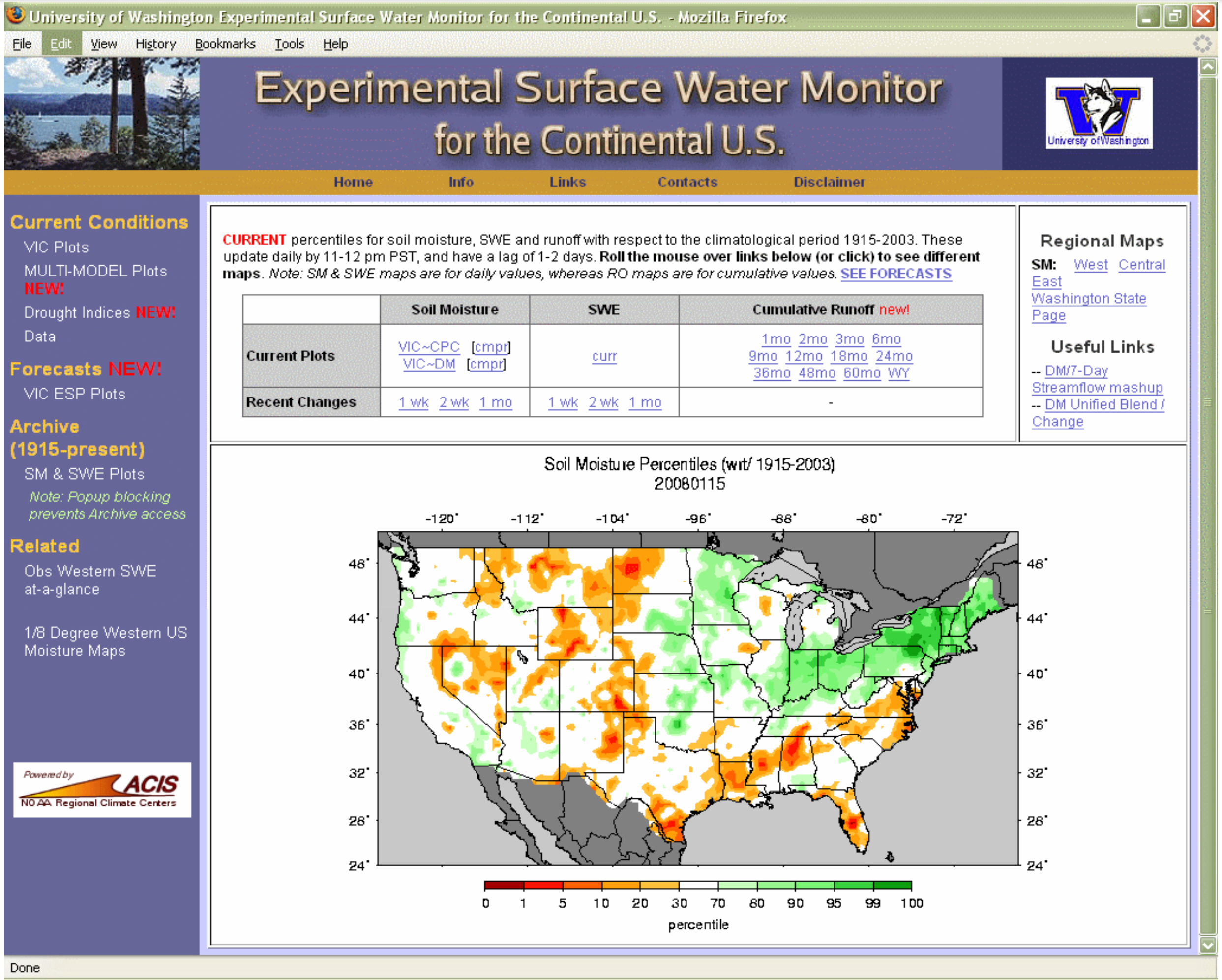
Some inputs are semi-objective

example blend

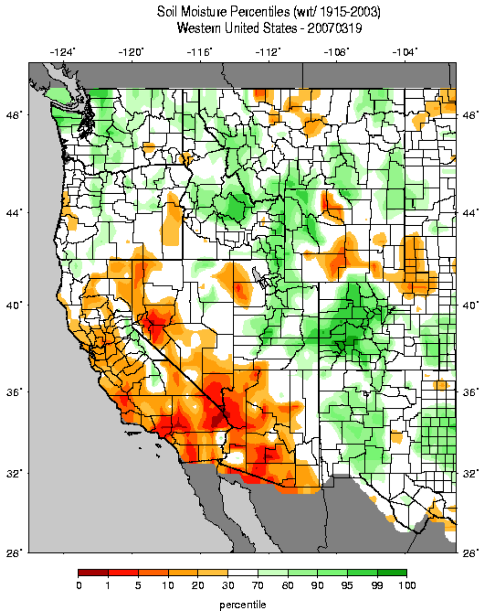
25% Palmer Hydrological Drought Index
20% 24-Month Precip.
20% 12-Month Precip.
15% 6-Month Precip.
10% 60-Month Precip.
10% CPC Soil Model



Objective drought-related monitoring systems have existed for over 20 years



- daily updates, half-day lag
- soil moisture, SWE, runoff
- **drought indices**
- ½ degree resolution
- archive: 1915 - now
- 3-month forecasts

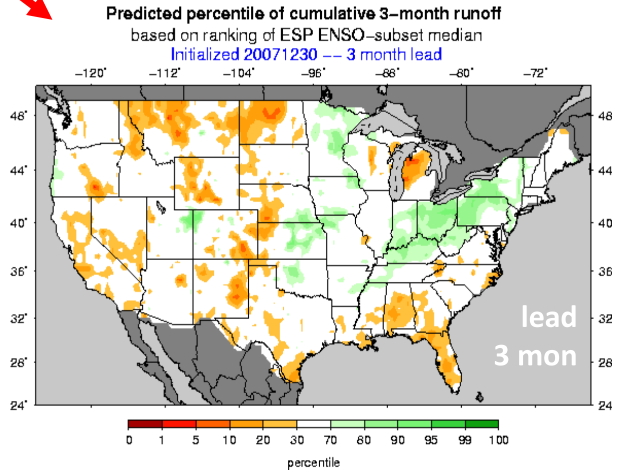


Wood, AW, 2008, **The University of Washington Surface Water Monitor: An experimental platform for national hydrologic prediction**, Proc. Amer. Meteor. Soc. Annual Meeting, New Orleans, 13 p. (available from http://ams.confex.com/ams/pdfpapers/134844.pdf).

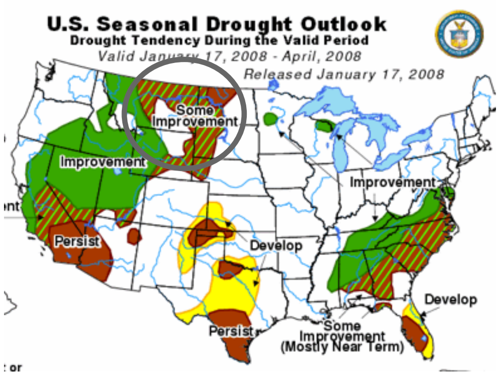
Surface Water Monitor *Prediction*, mid 2000s

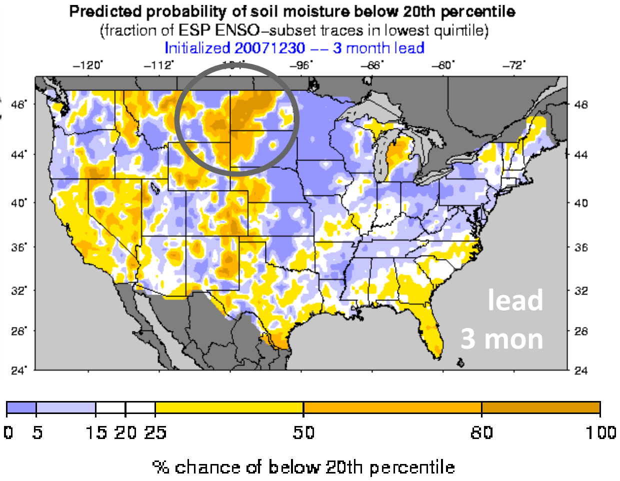
README	Soil Moisture	SWE	Cumulative Runoff new!
Current Percentiles	VIC~CPC	curr	3mo
Median Forecast Percentile	**CLIM:** lead1m lead2m lead3m **ENSO:** lead1m lead2m lead3m	-	**CLIM:** 3mo lead1m 3mo lead2m 3mo lead3m **ENSO:** 3mo lead1m 3mo lead2m 3mo lead3m
Forecast Prob. of below 20th percentile	**CLIM:** lead1m lead2m lead3m **ENSO:** lead1m lead2m lead3m	-	**CLIM:** 3mo lead1m 3mo lead2m 3mo lead3m **ENSO:** 3mo lead1m 3mo lead2m 3mo lead3m

Results were credible and the research activity eventually transitioned into agency practice

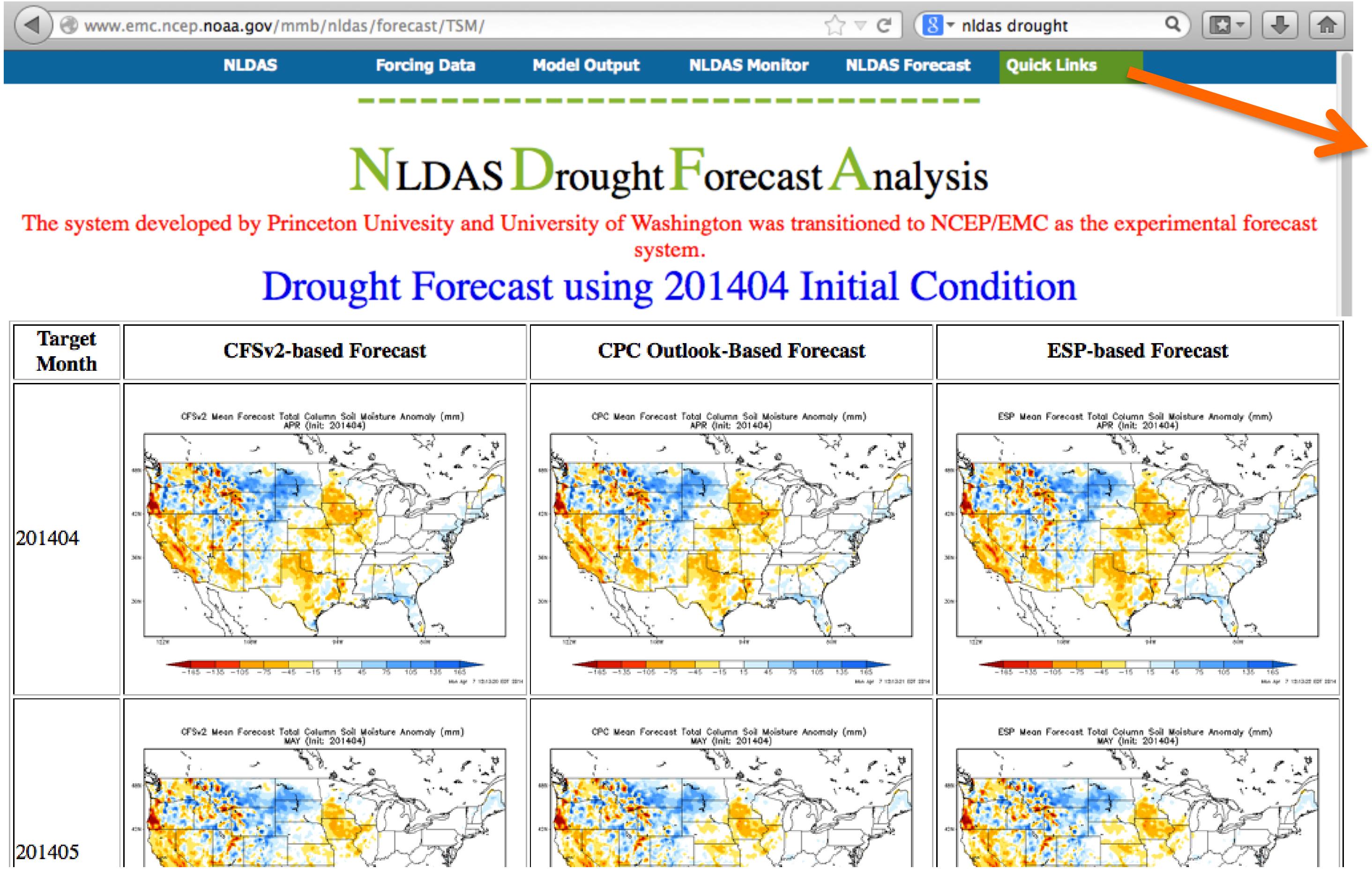


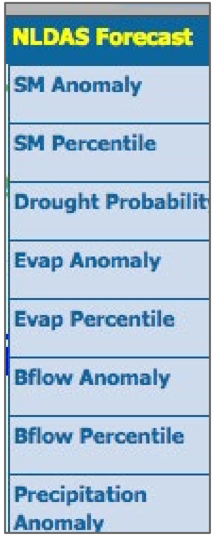
Probability of "drought persistence"





'Objective' Drought Projections





NOAA/NCEP transitioned the research work into a system that still runs (now by NASA GSFC) at

https://ldas.gsfc.nasa.gov/nldas/drought-monitor

The need and potential for an objective paradigm in drought monitoring

SC Prospects for Advancing Drought Understanding, Monitoring, and Prediction

Eric F. Wood, Siegfried D. Schubert, Andrew W. Wood, Christa D. Peters-Lidard, Kingtse C. Mo, Annarita Mariotti, and Roger S. Pulwarty

Print Publication: 01 Aug 2015

Collections: Advancing Drought Monitoring and Prediction

DOI: https://doi.org/10.1175/JHM-D-14-0164.1

In drought monitoring... a key success of the last decade has been the application and refinement of a modern class of hydrological models toward ***objective drought analysis****, including extended retrospective forcing datasets to support hydrologic reanalyses that are nearly a century long. Objective drought analysis is critical for developing retrospective drought indices and forecasts of drought because they provide objective consistency that is not available from the interpretive approaches behind the USDM. (Wood et al, 2015)*

Challenges

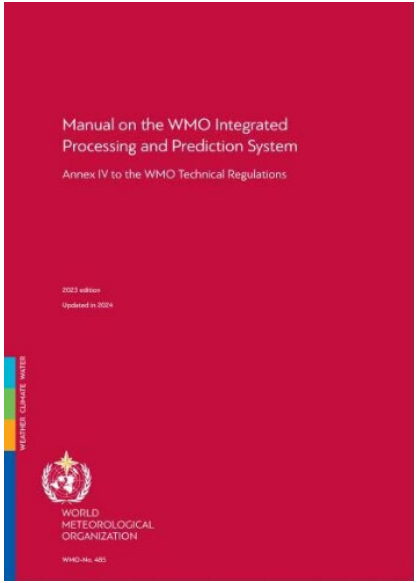
- Drought is multi-faceted, and individual model variables (such as soil moisture) do not fully represent different types of ‘drought’, though they are related.
- Automated land/hydromet modeling is not perfect, and there’s a need to reconcile clear local divergences

Opportunities

- Subjective consensus drought estimation is also not perfect, and cannot scale to encompass the expanding array of information or user needs
- Objective systems are reproducible, extensible, and can serve as benchmarks against which to assess new developments in an evidence driven way
- Objective systems can follow clear standards and protocols for information production.

Linking with international partners

- In certain parts of the world, drought-related services are organized differently than in the US, and useful ideas (around non-stationarity) may exist that can benefit US practice.



- Through the WMO, there is a current effort to **define standards for drought monitoring and prediction** systems that can participate in WIPPS, the WMO Integrated Processing and Prediction System.

- Some of this activity is related to WMO's Early Warning for All (EW4All) initiative.

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Advancing drought impact monitoring: a global baseline

NEWS

27 May 2025

The World Meteorological Organization (WMO) has released the report "Drought Impact Monitoring: Baseline Review of Practices" to address a critical gap: the lack of consolidated guidance on how to track and assess the wide-ranging impacts of drought.

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